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An empirical analysis of three stochastic inventory models in a naval hospital

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AN EMPIRICAL ANALYSIS OF
THREE STOCHASTIC INVENTORY
MODELS IN A NAVAL HOSPITAL

by

Floyd James Dunaway

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Exponential Smoothing proved to be slightly better, but no great differences were noted between the performances of the three models. One possible explanation was found to be excessive variance in the demand generated by the Pharmacy due to inputs other than actual customer demands. Recommendations were made for the institution of a basic system to aid the Pharmacy in determining their actual demand.

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I. INTRODUCTION

The ability to forecast demand is a vital part of any inventory management system. Generally such systems answer two questions about the items they manage; 1) How much to order, and 2) When to Order.[1] Forecasting assists in answering the first question (How much to order), therefore the ability to forecast accurately has a direct bearing on the performance of the total system.

Forecasting, as defined by Brown, involves the "projection of the past into the future", while prediction relates to "anticipation of changes and new factors affecting demand".[2] This separation of forecasting and prediction is important in that it binds forecasting to patterns of demand that have occured in the past. Thus, in Brown's view, forecasting has a historical background, whereas prediction has no real basis other than judgement and opinion. Among other experts in the field of forecasting, there is no absolute agreement on this point, and in fact the dividing line is at best obscure. Forecasting and prediction may be likened to objective and subjective methods of future demand determination; the subjective methods employ processes which are not well specified and not easily replicable, while objective methods use well specified processes, can be computerized, and can be easily redone by others if necessary.[3] For purposes of inventory management in a medical enviroment, the historical-based forecasting methods are generally preferable to

subjective predictions.

Within medical facilities, proper operation of the supply function is a necessity; stockouts could affect the mission of the activity and impair medical treatments. To guard against stockouts, the manager may elect to hold a certain level of items, commonly called a safety level, in reserve against the possibility of a stockout. The safety level is intended to provide a supplemental supply of items in excess of the forecast if the demand should exceed that forecast. The safety level increases the costs associated with holding that inventory, but as long as this cost is less than the cost of a stockout, the manager will elect to incur it. In this context, forecasting becomes doubly important. The medical inventory manager must be especially diligent about how he determines the amount of material he buys and stocks. The penalty for a stockout may be extreme, yet the manager is constrained from stocking material at a prohibitively high safety level by monetary, space, and manpower limitations. He must find a forecasting system that allows him to stock material at an acceptable safety level, yet minimize the costs associated with holding the material.

The rational supply manager will recognize the possibilities that a forecast may be either above the real demand observed, exactly equal to the demand, or fall short of the actual demand. Within stock fund limitations imposed by the Fleet Material Support Office, if he is above or exactly equal to the demand, he need not fear a stockout. (Navy medical supply managers finance their inventories through a working

capital fund called the Navy Stock Fund, which is administered and authorized on an activity-by-activity basis by the Fleet Material Support Office. This Office analyzes activity stock fund requirements quarterly, and grants Stock Fund monies based on these analyses. Each supply manager receives this analysis, the Regular/Supplemental Grant Worksheet, with the quarterly Stock Fund Allotment/Suballotment Authorization, and can ascertain the reasoning behind the stock fund grant)[4]

This paper will explore various forecasting models and their performance in stochastic demand situations. The demand data were gathered from the Naval Regional Medical Center, Oakland, California, and represents demand over time for items used by the Pharmacy in Federal Stock Class (FSC) 6505. These items were selected because they are among the most heavily used items in a medical facility, and are of paramount importance in patient treatment. As stated earlier, this paper's scope is limited to forecasting models, and will not address other inventory related topics such as reorder point determination, lead times, inventory cost determinations, and Economic Order Quantities. The reason for this limitation in scope is that forecasts are vital requirements of <u>all</u> inventory management systems; both civilian and military applications need them to carry out their functions. Also, forecasts can be tested empirically, with the output being applicable to that particular system.

In the military medical supply environment, the systems in use are generally simpler than other systems in use throughout the rest of the Supply System. The problems faced by the

Supply System in general are more complex (repairable items, sizeable numbers of reservation items, etc.) than the medical supply problems, and therefore the models at higher System levels are more sophisticated. The models in use at the medical activity level tend to be simpler, general models of the type used in managing smaller inventories. For instance, the model in use in medical activities without sophisticated data processing capabilities (manual labor intensive systems) is given by:

$$\frac{\text{Annual Demand Quantity}}{12} \times 2 = \text{Reorder Point}$$

$$\frac{\text{Annual Demand Quantity}}{12} \times 5 = \text{Requisitioning Objectives}$$ [5]

This model is representative of the type used in a wide variety of civilian and military inventory systems for manual and simple E.A.M. applications. The first part of each equation, Annual Demand Quantity/12, is a moving average that gives a forecast of demand for the next month based on the monthly average for the past twelve months. The second part of each of the two equations, multiplications by two and five respectively, give inventory maintenance levels based on that forecast.

It can be seen that the forecast is an element of inventory management that is essential to all systems; analysis of an inventory topic not common to all systems would have limited the study's usefulness. It was for this reason that the decision was made to limit the study to forecasting.

II. PROBLEM DEFINITION

At the beginning of the study (and currently), the forecasting model in use at the Naval Regional Medical Center, Oakland, California was the following;

$$\frac{CD + 2(OP_1)}{3} = OP_2$$

CD = Current Demand

OP_1= Order Point Last Month

OP_2= Order Point Current Month

Many questions can be asked about this model;

1) Who had originally formulated and implemented the model?
2) Had any studies been done prior to implementation?
3) Would another stochastic model do better?

Interviews with the Supply Officer of the Regional Medical Center revealed that the origin of the model was completely unknown. No one in the Supply Department or the Data Processing Division knew who had originally programmed the model. The model was a part of the reorder program run for the Supply Department by the Data Processing Division, and had been in use for a long period of time, with even its original implementation date unknown. The Supply Officer, in an effort to learn more about the model and its effects on costs and stock levels, had to request a print out of the reorder program, then analyze it in depth to understand the basic format of the model set forth above. It was quite evident that the forecasting model in use was poorly understood in terms of its

origin and effects on supply operations.

The effects on costs and stock levels of the model forecasts were also unclear. With no other data to evaluate then the actual performance of the model, no comparisons could be made and no judgements arrived at. The Supply Officer, in an effort to lower costs and improve performance relative to supply levels within his department, sought more information concerning the model he was using. A study of the model in use, along with the modification to it and other stochastic models that could be used, was decided upon as the best vehicle to see if improvements were possible.

III. ANALYTICAL APPROACH

To address the problems of how well the system performs in relation to other stochastic models, what the effect of other changes to the present model would be, and how well the present and other models do in meeting the demand, an empirical study of the present system and alternate forecasting models was undertaken. An empirical study was decided upon primarily because it would use the inputs (demand, unit prices) of the actual system to be evaluated and reflect the performance of forecasting models relative to the actual system.

The framework of the study included three steps;

1) The selection of a sample of inventory items to use in conjunction with forecasting models under study
2) An analysis of forecasting models in actual operation with the sample

3) An evaluation of the forecasting model performance in a managerial context

The items carried by the Pharmacy at the Naval Regional Medical Center were selected as the source of the sample, as they represent some of the most important and heavily used items in the hospital setting. FSC 6505 items (drugs) are held in stock by the Supply Officer, and are drawn by the Pharmacy for the filling of prescriptions. Within the hospital setting, the Supply Officer represents the system supply of items available upon demand by the Pharmacy. The Pharmacy, as the end-user of the items, creates the demand for the FSC 6505 items when it requisitions them from the stock the Supply Officer holds.

The system to be empirically tested sets the reorder amounts in the Supply Department to insure material availability for the Pharmacy and other supply users. The Pharmacy generates demand through the requisitioning process, and a history of these demand figures are retained and used by the Supply Officer. The forecasting model uses these demand figures to forecast demand in the upcoming period (one month), and procurements of material for the Supply Department are made based on the forecasts. The value of the forecast is measured by how well the forecast foretells the demand and prompts procurement action to meet it.

A demand history of twelve months accumulated demand recorded in the Retail Asset Stock Card (RASC) was used as the basis for sample selection (see Research Methodology). Eighteen months of recent demand figures were then collected and used

for model verification and forecasting comparisons. Various models were run with the sample of the FSC 6505 items selected, and the forecasts were compared to actual demands using the last two months as a primary test. The comparison of the forecasts to the actual demand were done in a managerial context; the assumption was made that the Supply Officer bought the amounts forecasted by the model, and the demand for the period is taken from the procured forecast. For each item, one of three conditions is possible; 1) The forecast will be greater than the actual demand, in which case there will be a surplus of material, and 2) The forecast will exactly equal the demand, in which case there will be no difference, and 3) The forecast will be less than the actual demand, in which case there will be a shortage of material.

The evaluation of the forecasting model was done in two phases; an evaluation of the differences between the forecasts and actual demand, and an evaluation of the value of material associated with those differences. For each model, the total number of differences will be examined, with a view toward maximizing the total availability (at the least cost of inventory). There will be two resulting material values, the value of material purchased that exceeds demand, and the value of material demanded that exceeds the forecast. The values are then summed to give the total material value. This results in weighing the value of material purchased that exceeds demand and the value of material demand that exceeds the forecast equally.

IV. RESEARCH METHODOLOGY

A. DATA COLLECTION

To test the stochastic models under consideration, a sample was required from the population of 1,006 items in FSC 6505 held by the Pharmacy at the Naval Regional Medical Center, Oakland.

The demand information required for the line items was contained on the Retail Asset Stock Cards (RASC), compiled and sent to the Fleet Material Support Office, Mechanicsburg, Pennsylvania on a semi-annual basis. There is one card in the RASC deck for each item. Various information was contained in separate fields on each card as described in Appendix 1. The FSC is contained in columns 8 through 20, Unit of Issue in columns 23 and 24, 12 Month Demand in columns 57 through 62, and Unit Price in columns 70 through 76. The FSC 6505 section of the RASC deck submitted by the Regional Medical Center, Oakland in April of 1978 was reproduced by the Fleet Material Support Office and forwarded to the Postgraduate School for analysis.

Two fields on the RASC cards were selected for analysis; the 12 Month Demand field and the Unit Price field. The total demand for the item over the twelve months preceeding the date of card submission was recorded in the 12 Month Demand field, and the Unit Price field held the system-designated unit price for the item. The demand figures were of primary interest, as the demand figures were used as inputs

to the models under analysis.

To analyze the fields, one of the programs in the BMDP-77 Biomedical Computer Programs (P-Series) was used. The BMDP series of programs, developed by the Health Sciences Computing Facility of the University of California, provides a set of easily understood and utilized computer programs that will do a wide variety of analyses, comparisons, regressions, and plots on data inputted by the user. The program used for the initial analysis was the P5D program, Histograms and Univariate Plots. The program's output is in the form of a histogram of the items in the field or fields designated, frequencies within the intervals of the histogram, percentages within the intervals, and the mean and standard deviation of the items. The 1,006 FSC 6505 cards were run with the required Control Language cards (Appendix 2), and the output of the program was obtained.

The 12 Month Demand field was examined first. The mean of all 1,006 items was 548.009, and the standard deviation was 1374.880. There were fifty intervals in the histogram, each interval containing 12 Month Demand Quantities. The interval boundaries were established by the P5D program, and all 12 Month Demand quantities within those limits were contained in the interval. Twenty four intervals contained demand quantities. The first seven intervals accounted for 96.2% of the demand (968 of the 1,006 items) with an upper limit of 2940 units of 12 Month Demand. Analysis of the first interval revealed that 34 of the 724 items in the interval held Ø demand in the 12 Month Demand field, and were

eliminated from the deck, leaving 690 items in the first interval. Since the remaining seventeen intervals (after the first seven intervals) contained only 38 items, or 3.8% of the total, a decision was made to disregard them in the selection of the sample. It was felt that the selection of an item from this group and its inclusion in the sample would not result in a representative sample; accordingly these items were treated as outliers. As a result, the sample would be drawn on a stratified sample basis from the first seven intervals. The interval limits, frequencies, and percentages are outlined below;

12 Month Demand

Intervals		Frequencies		Percentages	
Upper Limit	Lower Limit	Int.	Cum.	Int.	Cum.
420	0	690	690	73.8	73.8
840	420	140	830	14.9	88.7
1260	840	38	868	4.0	92.7
1680	1260	29	897	3.1	95.8
2100	1680	14	911	1.5	97.3
2520	2100	13	924	1.4	98.7
2940	2520	10	934	1.3	100.0

The Unit Price field was analyzed using the same program, P5D, Histograms and Univariate Plots. Again, the output was a histogram divided into fifty intervals, with each interval containing Unit Prices. Nineteen intervals contained Unit Price data, with 98.7% of the items contained in the first

ten intervals. Only twelve items, or 2.3% were located in the remaining nine intervals. The mean of the Unit Price data was $13.64, and the standard deviation was $27.05. The intervals, frequencies, and percentages of the first ten intervals are illustrated below:

Unit Price

Intervals*		Frequencies		Percentages	
Upper Limit	Lower Limit	Int.	Cum.	Int.	Cum.
10	0	689	689	69.3	69.3
20	10	125	814	12.5	81.8
30	20	67	881	6.7	88.5
40	30	36	917	3.6	92.1
50	40	28	945	2.8	94.9
60	50	17	962	1.7	96.6
70	60	18	980	1.8	98.4
80	70	5	985	.6	99.0
90	80	4	989	.5	99.5
100	90	4	993	.5	100.0

* The range of the intervals are in $10 increments.

As noted earlier, the 12 Month Demand field was selected as the source for the stratified sample, as the demand histo histories for the items would be used as the inputs into the inventory models.

The RASC deck was sorted according to the upper and lower limits indicated on the 12 Month Demand histogram, resulting

in seven groups of cards, one group for each of the first seven intervals. Each interval card group was run through the BMDP P1D program of the BMDP Series, the P1D program being a Simple Data Description program. The program output was a complete listing of the group by item and number, actual 12 Month Demand, and Mean and Standard Deviation figures. Seven listings, one for each interval, resulted.

The size of the sample was set at 100 items, approximately 10% of the 968 remaining FSC 6505 items. The 100 items were selected from the seven intervals using the formula:

$$\frac{X}{Y} \times 100 = Z$$

X = Number of items in the interval

Y = Total number of items in all seven intervals

Z = Number of sample items to be selected from the interval

The problem then was to select items of the required sample size from each interval. The procedure used was a modified random scheme using program ST1-04, Random Number Generator, one of the Statistics Library programs sold for use with the Texas Instruments SR-52 Programmable Calculator. The program uses the Mean and Standard Deviation of the individual intervals to generate normal deviates within each interval. For instance, the required 75 random deviates for interval 0 through 420 were generated from a normal distribution having mean 119.376 and standard deviation 109.567. As the normal deviates were generated, they were translated into individual sample items by matching with corresponding items listed on the print-outs from program BMDP P1D, Simple Data Description.

Each interval print-out had each item in the interval listed, along with the value of the 12 Month Demand associated with that item. As a normal deviate was generated, it was matched with the corresponding value in the 12 Month Demand field, and that item became one of the sample items. The required number of sample items were selected from each interval, and the result yielded a representative sample with the highest likelihood of selection near the midpoint of the interval. The items in each interval, number of sample items selected from each interval, and Mean and Standard Deviation of each interval are listed below;

Interval Upper Limit	Interval Lower Limit	Interval Mean	Interval Std. Dev.	Interval Total Items	Sample Size
420	0	119.376	109.567	690	75
840	420	592.613	121.183	140	15
1260	840	1050.708	114.155	38	04
1680	1260	1445.929	123.401	29	03
2100	1680	1853.213	126.307	14	01
2520	2100	2289.307	128.850	13	01
2940	2520	2750.000	139.784	10	01
				934	100

After selection of the sample, the Means and Standard Deviations of the Intervals and the Samples were as follows:

Interval Upper Limit	Lower Limit	Means Interval	Sample	Interval	Sample
420	0	119.376	139.94	109.567	86.15
840	420	592.613	552.00	121.183	81.18
1260	840	1050.708	993.25	114.155	69.37
1680	1260	1445.929	1441.00	123.401	16.52
2100	1680	1853.213	1771.00	126.307	--*
2520	2100	2289.307	2406.00	128.850	--*
2940	2520	2750.00	2876.00	139.784	--*

* No Standard Deviation given as only one item in sample

The Unit Price comparisons were as follows:

FSC6505 Items (1,006) Mean	Std. Dev.	Sample Items (100) Mean	Std Dev.
$13.64	$27.05	$14.42	$47.91

The end result was a stratified sample numbering 100 items drawn from the FSC 6505 group numbering 1,006 items.

Since the sample was identified by Stock Number for each item, the collection of demand history was considerably facilitated. At The Naval Regional Medical Center, the demand history is called the Usage History, and figures for January 1977 through June 1978 and July and August 1978 were collected. For each item in the sample, eighteen months of demand history figures were assembled. In addition, two months of validation figures were collected, (months nineteen and twenty) for use in forecast comparison. The eighteen months of history would be used to generate forecasts and establish demand patterns.

Subsequently, the additional two months of history would be used to test the forecasts of demand for those two months. The eighteen months of demand data were transferred to machineable cards for use in the analysis. The Stock Number was included in Columns one through eight, while demand data were included in eighteen blocks of four columns each; all eighty columns of the card were used. The full deck of 100 sample cards with the demand histories included bacame the Source Deck for computer analysis.

B. MODELS

Three models were selected for analysis; 1) A3RSR Method, 2) Exponential Smoothing Model with differing alpha values, and 3) Regression Forecasting.

1. A3RSR

The A3RSR Smoothing Method is actually an adaptation of a Tukey smoothing model into a forecasting model. A3RSR is the name given to a smoothing technique developed by Tukey and presented in the book Interactive Data Analysis by Donald R. McNeil.[6] As adapted for demand forecasting application, the smoothing is first applied to random data from a time series. The technique smooths the randomness into a relatively smooth curve, facilitating trend analysis and making forecasting possible.

In actual operation, the smoothing is accomplished using running medians of three. The ith response in the series y(i-1), y(i), and Y(i+1) is replaced by the median of the three points. End points are treated by replacing

y(1) by the median of y(1), y(2), and 3(y(2))-2(y(3)). The treatment of the last point in the series is handled in the same manner. It is this end point rule that makes the forecasting possible. The use of median replacement in the time series data produces <u>mesas</u>, or pairs of adjacent points with a common value which is below or above the points on each side. The median replacement is repeated until the mesas are split and finally dissapear. The whole process can be viewed as a gradual erosion of the roughness of the original data in repeated small steps until no further smoothing by medians is possible. In fact, the '3RSR' part of the name refers to "medians of 3, repeated until convergence, split, repeated until convergence".[7] The "A" part of the name refers to the use of medians as a basic component of the smoothing as opposed to a "B" technique, explained by Mr. McNeil in his book.[8]

At the Naval Postgraduate School, the A3RSR program is part of the OA366Ø APL Public Library on file in the IBM 360/70 Computer in the W.R. Church Computer Center. Data were transformed into the correct APL format for the program, the program run, and the forecast gathered as follows;

The Source Deck (demand history cards) was read into the computer, and set up by a FORTRAN program into a file named FTO4F001. The APL mode was entered, and the file FTO4F001 was read and transformed into an APL formatted file named FTO8F001. File FTO8F001 was renamed 'DEMAND', and the Stock Number deleted from the file. The final form of the file named 'DEMAND' was a line of demand data for each item in

an APL format, where each item is accessed by requesting the file name, then the numerical number in the sequence (the third item is requested by the command DEMAND (3;)). The Public Library OA366Ø was copied into the APL workspace, and each item in the 'DEMAND' file was run through the A3RSR program. The result was assigned the value of 'C' (e.g. C ← A3RSR DEMAND (21;)) and 'C' was printed out. The last numerical value in the print-out of 'C' was used as the A3RSR forecast for the next period (Appendix 3).

2. Exponential Smoothing

The Exponential Smoothing technique, set forth in a book entitled Statistical Forecasting for Inventory Control by Robert G. Brown, published in 1959, is essentially a weighted moving average method of smoothing.[9] It uses the demand for the present period (d_t), and the forecast for the last period (U_{t-1}), and a constant labled 'α' to develop the forecast for the upcoming period (U_t). Mathematically, the formula appears as follows;

$$U_t = (\alpha)\ (d_t) + (1-\alpha)\ (U_{t-1})$$ [10]

U_t = Forecast for upcoming period

d_t = Demand for the present period

U_{t-1} = Forecast for the last period

As the new demand figures for the present period (d_t) become known, they are worked through the formula with the constant α and the forecast for the last period (U_{t-1}) to generate the new forecast (U_t). Exponential Smoothing is especially adaptable to data processing in that only the value

for the last forecast (U_{t-1}) need be stored for each item, making for a minimum amount of storage.[11]

One facet of the Exponential Smoothing model is the fact that the value for α can be changed to give different weights to the demand in the present period (d_t) and the forecast for the last period (U_{t-1}). Analysis of the present model in use at the Naval Regional Medical Center, Oakland reveals that the model is in actuality an Exponential Smoothing model with an α value equal to 0.333. See below;

$$\frac{CD + 2(OP_1)}{3} = OP_2 \text{ is equivalent to } \frac{1}{3}(CD) + \frac{2}{3}(OP_1) = OP_2$$

CD (d_t) = Current Demand (present period)

OP_1 (U_t-1) = Forecast (Order Point) Last Period

OP_2 (U_t) = Forecast (Order Point) for upcoming period

This ability to change the value of α raises the question of the possible benefits of changing the values and thereby changing the weights. In the course of the study, the decision was made to analyze the effect not only of the current α value (0.333), but also the other α values. The values selected were 0.001, 0.01, 0.025, 0.05, 0.1, 0.2, 0.333 (present system), 0.5, and 0.7. The values lower than 0.5 put ever increasing weight on the forecast for the last period (Ut-1), the value of the 0.5 puts equal weight on both the current demand (d_t) and the forecast for the last period (U_{t-1}), and values greater than 0.5 put the preponderance of weight on the current demand (d_t). By using these values of in the analysis, the effect of changing weights in the formula

can be assessed, and the effect of changes in the present system formula can be illustrated for comparison with the other models.

In actual operation, a FORTRAN program was written to develop the forecast for the nineteenth and twentieth months (Appendix 4). Once the forecasts were printed by the program, they were compared to the actual demands for the periods, and the deviations were recorded.

3. Regression Forecasting

Regression forecasting employs standard and well-known regression formulas with time-series analysis.[12] Standardized formulas use the demand data inputs to give the Slope and Y-Intercept of the data set, while the time-series element is brought in by including time data (y(i)).[13] The regression forecasting rule used in this study is based on the format;

$$y(i+1) = \text{Y-Intercept} + \text{Slope } (y(i))$$ [14]

The formula is derived from the standard linear regression model in which a straight line is fitted through data points using the method of least squares. The data thereby yield estimates of the Y-Intercept and Slope which are then used in the actual forecast.

To effect this procedure, the eighteen month demand data were processed through the 'LINE' program of the OA366Ø APL Public Library, which resulted in Slope and Y-Intercept figures for the demand data. The APL commands to use the 'LINE" program are, for example;

```
D  ←  DEMAND (16;)
W  ←  LINE D
SLOPE: 1.052      Y-INTERCEPT:  0.932
```

The first command assigns to 'D' the values of the eighteen demands in the 16th line of the 'DEMAND' file, while the second command runs the values of 'D' through the 'LINE' program and assigns the estimated values of the Slope and Y-Intercept to 'W', which is then printed out in the form of line 3. The forecasts for both the nineteenth and twentieth months are developed in this way, and are compared to the actual demands for these periods.

C. ANALYSIS

As stated earlier, the eighteen months of demand history for each sample item were entered on machineable cards with the Stock Number for each item, which resulted in a 100 card Source Deck to be used as the input into the various stochastic models.

To get a pictorial view of the eighteen month demand for each item, another program in the OA366Ø APL Public Library was used, the 'SCAT' program. This program plots a graph of the data points, placing the demand values on the Y axis and the individual months on the X axis. A demand scattergram is created by the program that visually depicts the demand values over the months included. Each item in the sample was run through the 'SCAT' program so that an idea of the overall pattern of the demand points for each item could be seen.

The A3RSR forecasts were developed as explained in the

A3RSR model section for each of the two months for which data was available. The forecasts were listed along with actual demand recorded for each month, and notations were made of the differences.

The Exponential Smoothing forecasts were developed for each value of α from the FORTRAN program as outlined in Appendix 4. The forecasts were listed along with the actual demands recorded for each month, and notation made of the differences.

The Regression Forecasts were developed as outlined in the Regression Forecast section for each of the two months for which data was available. The forecasts were listed along with the actual demands recorded for each month, and notation made of the differences.

Differences between forecasts and actual demand for each item were illustrated by the following examples;

Stock No.	Forecast	Demand	Difference
111-1900	35	30	+5
231-7821	27	27	00
235-8100	73	98	-25

The differences are explained in a managerial context: The assumption is made here that the Supply Officer purchases the amount indicated by the forecast to meet the upcoming demand. If the purchased (forecasted) amount exceeds the demand (as in the first case above), a surplus exists at the end of the period. If the purchased (forecasted) amount exactly meets the demand (as in the second case above), there is zero difference. If the purchased (forecasted)

amount is less than the demand (as in the third case above), a shortage exists at the end of the period. For each model evaluated, the number of surpluses, zero differences, and shortages will sum to 100, the size of the sample evaluated.

The measure of differences forms the basis of the quantitative cost evaluations for each model. The differences for each item are multiplied by the Unit Price of that item, giving either the value of material that would have been required to meet the demand if the forecast had been accurate or a value of material demanded that exceeds the forecast. If a model were 100% correct in forecasting demand, there would be no dollar value differences associated with the model (dolar value differences as defined in the preceeding sentence, of course). The only dollar values would be the value of material purchased that exactly met the demand. It should be recognized that no model will be 100% correct (due to the stochastic nature of the demand), so there will inevitably be values of material purchased that exceed demand and values of material purchased that exceeded the forecasts associated with each model.

V. FINDINGS AND CONCLUSIONS

As stated earlier, forecasts were developed from each model using the formulas described in the Research Methodology section. If a forecast was in decimal form, it was rounded to the next whole number (e.g. 1.6 was rounded to 2.0); this was done to conform to the managerial context of the analysis.

The manager, under this assumption, purchases the forecast, and rounding the decimal forecast is required to determine the number of units to procure.

The forecasts were compared to the actual demands for the two months under study, and the differences enumerated for each model. The differences are listed below;

Model	19th Month	20th Month	Total	Per-Cent
A3RSR				
(+)	61	42	103	51.5
(Ø)	12	13	25	12.5
(-)	27	45	72	36.0
	100	100	200	100.0
Ex. Sm. (0.001)				
(+)	58	48	106	53.0
(Ø)	04	10	14	07.0
(-)	38	42	80	40.0
	100	100	200	100.0
Ex. Sm. (0.01)				
(+)	60	46	106	53.0
(Ø)	02	06	08	04.0
(-)	38	48	86	43.0
	100	100	200	100.0
Ex. Sm. (0.025)				
(+)	62	51	113	56.5
(Ø)	03	02	05	02.5
(-)	35	47	82	41.0
	100	100	200	100.0

Model	19th Month	20th Month	Total	Per-Cent
Ex.Sm. (0.05)				
(+)	63	49	112	56.0
(Ø)	05	02	07	03.5
(-)	32	49	81	40.5
	100	100	200	100.0
Ex. Sm. (0.1)				
(+)	67	47	114	57.0
(Ø)	07	06	13	06.5
(-)	26	47	73	36.5
	100	100	200	100.0
Ex. Sm. (0.2)				
(+)	71	48	119	59.5
(Ø)	06	07	13	06.5
(-)	23	45	68	34.0
	100	100	200	100.0
Ex. Sm. (0.333)				
(+)	73	52	125	62.5
(Ø)	02	04	06	03.0
(-)	25	44	69	34.5
	100	100	200	100.0
Ex. Sm. (0.5)				
(+)	75	49	124	62.0
(Ø)	00	07	07	03.5
(-)	25	44	69	34.5
	100	100	200	100.0

Model	19th Month	20th Month	Total	Per-Cent
Ex. Sm. (0.7)				
(+)	72	41	113	56.5
(Ø)	01	13	14	07.0
(-)	27	46	73	36.5
	100	100	200	100.0
Regress. Fore.				
(+)	63	35	101	50.5
(Ø)	08	10	18	09.0
(-)	29	52	81	40.5
	100	100	200	100.0

On the basis of the absolute values of the total positive and zero differences (which reflect the ability of the system to fill the demand when first requested), the Exponential Smoothing model with an alpha value of 0.2 forecasted best both within the Exponential Smoothing group and against the other two models. Viewed in the context of the restricted number of months compared (two), the differences in the models were not considered to be alarming, in that the total variance range between the two models was only 6.5%. If more periods had been available, it would have been reasonable to expect that the percentages would change, and a better evaluation of the first pass availability would be possible.

To assess the differences over a longer period of time, a smaller sample consisting of the mean items from each interval was run with the A3RSR, Exponential Smoothing (alpha= 0.2), and Exponential Smoothing (alpha= 0.333) models

for a period of sixteen months. The full twenty months of data was used, but due to a pecularity in the A3RSR program, the first four months of demand data could only be used to develop forecasts. The running of the entire 100 items in the sample for a period of sixteen months was considered to be a task of too great a magnitude given the time constraints of the study, so the mean items in each interval were chosen as a representative sample of the 100 items. The results are illustrated below;

A3RSR		Ex. Sm. (0.333)		Ex. Sm. (0.2)	
(+)	55	(+)	59	(+)	59
(Ø)	04	(Ø)	02	(Ø)	01
(-)	53	(-)	51	(-)	52
	112		112		112

As can easily be seen, the differences are consistent with the results on the larger sample. Model performance over time appeared to be not greatly different from performance over the two month period.

The dollar values derived from multiplying the differences by the Unit Price of the items were summed and are presented below;

Models	19th Month	20th Month	Total
A3RSR			
(+)	$7,026.60	$4,410.74	$11,437.34
(-)	2,252.92	4.233.22	6,486.14
Total	$9,279.52	$8,643.96	$17,923.48

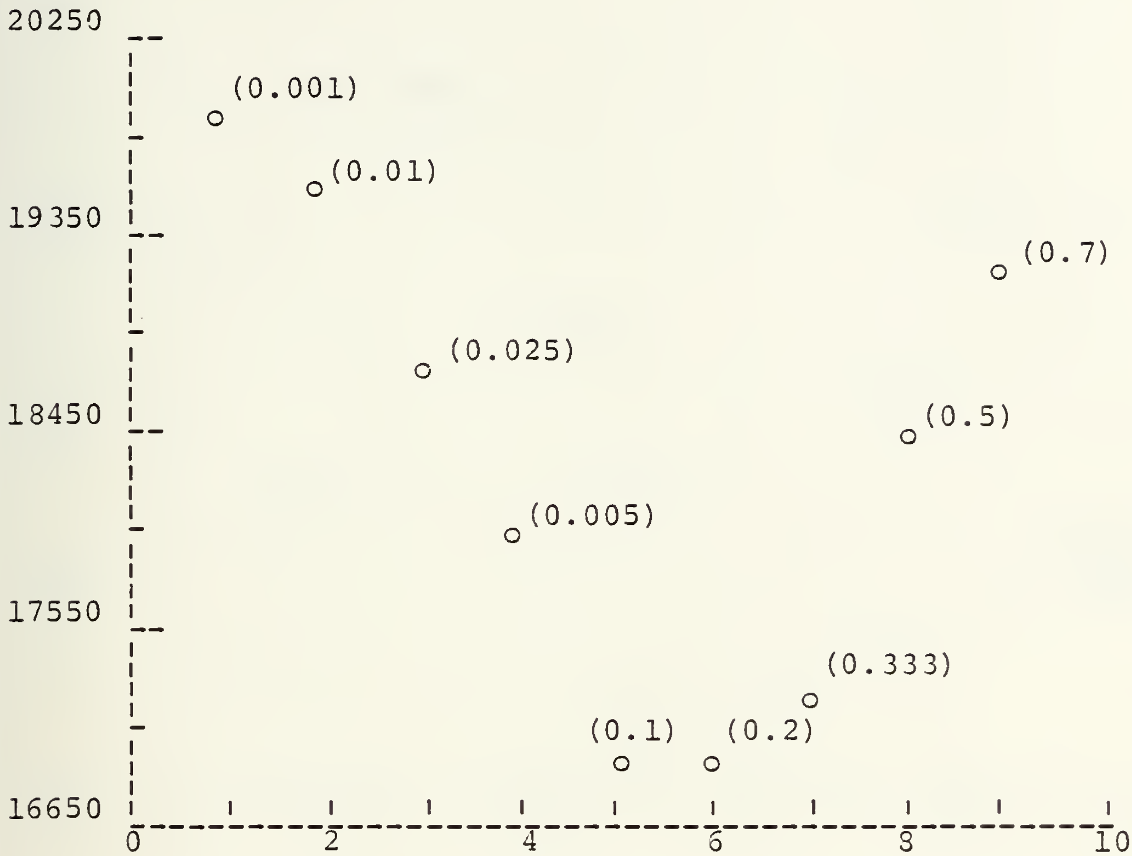
Models	19th Month	20th Month	Total
Ex. Sm. (0.001)			
(+)	$5,838.21	$4,999.02	$10,837.23
(-)	3,463.86	5,630.41	9,094.27
Total	$9,302.07	$10,629.43	$19,931.50
Ex. Sm. (0.01)			
(+)	$5,950.90	$4,966.28	$10,917.18
(-)	3,205.32	5,388.83	8,594.15
Total	$9,156.22	$10,355.11	$19,511.33
Ex. Sm. (0.025)			
(+)	$5,838.17	$4,941.56	$10,779.73
(-)	2,778.44	5,142.71	7,921.15
Total	$8,616.16	$10,084.27	$18,700.88
Ex. Sm. (0.05)			
(+)	$6,008.51	$5,140.74	$11,149.25
(-)	2,372.18	4,352.22	6,724.40
Total	$8,380.69	$9,492.96	$17,873.65
Ex. Sm. (0.1)			
(+)	$6,231.65	$5,184.84	$11,416.49
(-)	1.701.73	3,764.55	5,466.28
Total	$7,933.38	$8,949.39	$16,882.77
Ex. Sm. (0.2)			
(+)	$6,956.45	$5,137.30	$12,093.75
(-)	1.308.57	3,453.01	4,761.58
Total	$8,265.02	$8,590.31	$16,855.33

Models	Month	Month	Total
Ex. Sm. (0.333)			
(+)	$7,430.78	$5,021.22	$12,452.00
(-)	1,320.30	3,472.40	4,792.70
Total	$8,751.08	$8,493.62	$17,244.70
Ex. Sm. (0.5)			
(+)	$8,529.48	$4,696.46	$13,225.94
(-)	1,289.45	3,838.90	5,128.87
Total	$9,819.45	$8,535.36	$18,354.81
Ex. Sm. (0.7)			
(+)	$8,924.47	$4,549.26	$13,473.73
(-)	1,351.90	4,290.72	5,642.62
Total	$10,276.37	$8,839.98	$19,116.35
Regress. Fore.			
(+)	$6,527.70	$5,137.97	$11,665.67
(-)	1,758.42	4,178.86	5,937.28
Total	$8,286.12	$9,316.83	$17,602.95

In terms of absolute dollar value, again the Exponential Smoothing model with an alpha value of 0.2 performs the best (gives the lowest dollar values) in relation to the other other models. When evaluated as to the magnitude of the value differences, the models perform nearly equally.

Changing the values of alpha in the Exponential Smoothing models produced differing dollar values, which proved to be lowest where the alpha value equalled 0.2.

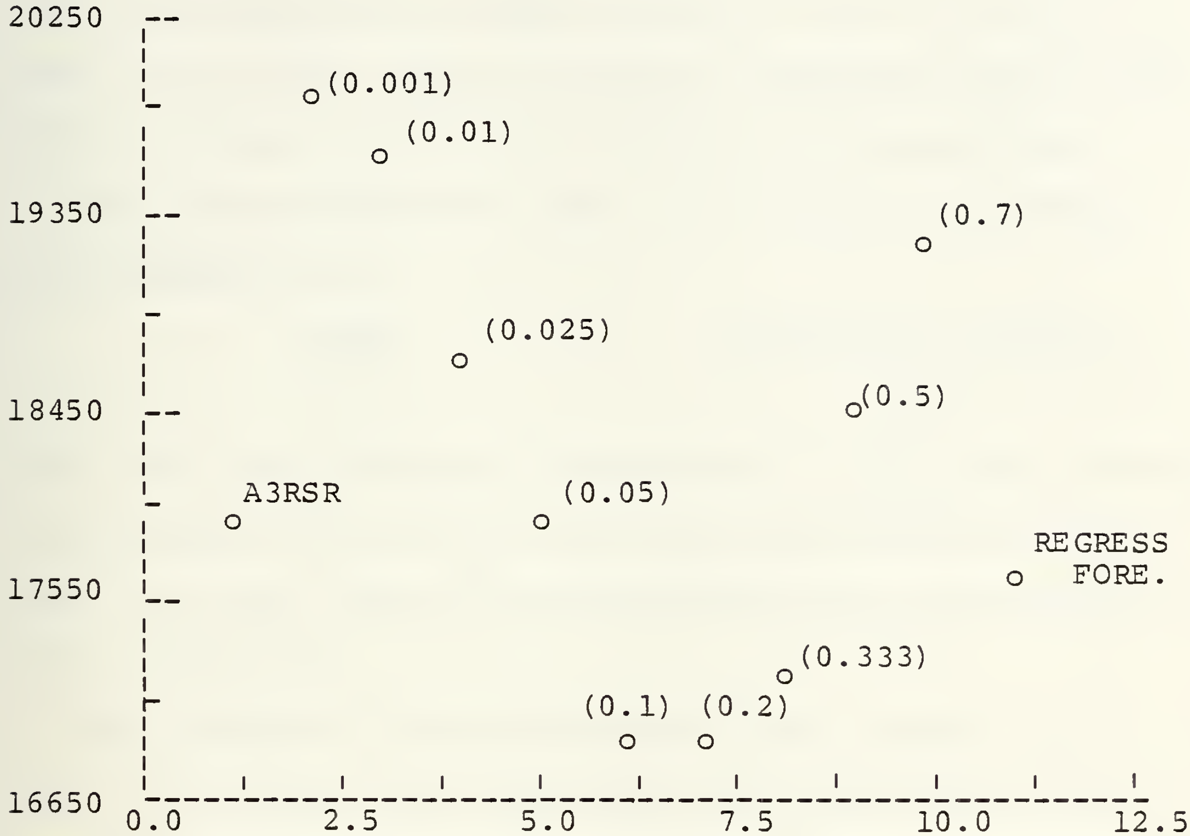
These empirical results can be best seen in the graph below



Alpha Values	Total Dollar Values
0.001	$19,931.50
0.01	$19,511.33
0.025	$18.700.88
0.05	$17,873.65
0.1	$16,882.77
0.2	$16,855.33
0.333	$17,244.70
0.5	$18,354.81
0.7	$19,116.35

An overall graph of the Exponential Smoothing model with the

different values of alphas and other stochastic models proved to be very interesting;



<u>Other Models</u>	<u>Total Dollar Values</u>
A3RSR	$17,923.48
Reg. Fore.	$17,602.95

As can easily be seen, not all the Exponential Smoothing variations did better than the A3RSR and Regression Forecasing. Only certain values of alpha produced total dollar values in the Exponential Smoothing model better (Lower) than both the other models (0.1, 0.2, 0.333). Even for those values below the values of the A3RSR and Regression Forecasting models, the differences were not large enough to give unqualified approval to the Exponential Smoothing model above all others.

One notable fact is that the total value for the model currently in use at the Naval Regional Medical Center, Oakland (Expoential Smoothing with an alpha value of 0.333) is lower in total dollar value than the A3RSR and Regression Forecasting models, and falls below both of them on the graph above.

The Value Difference/Ex. Sm. (0.2) Value of the models are presented below;

A3RSR	Regression Forecast
6.3%	4.4%

Here, as in the differences comparison, the percentage range of variation was within 6.5%, leading to the conclusion that there is no real great difference between the three models in their performance.

The valuation of the differences (total dollar value) found in the mean items drawn from the sample and run with the forecasting models tended to support the results discovered in the 100 item sample. The period was sixteen months, but the results followed the same pattern as the two month primary test;

	A3RSR	Ex. Sm. (0.333)	Ex. Sm. (0.2)
	(+) $9,921.31	(+) $9,556.03	(+) $9,002.02
	(-) 9,645.91	(-) 9,383.89	(-) 9,211.99
Total	$19,567.22	$18,939.92	$18,214.01

Here again, in absolute dollar value terms, the Exponential Smoothing model with an alpha equal to 0.2 proved to be the best. The magnitude of the differences, however, was not large enough to give an overall endorsement to the Exponential

Smoothing model.

The finding that there was no large difference between the performance of the three models led to an attempt to discover why. A more significant variation in model performance had been expected due to the difference in forecasting approaches inherent in each model. Yet it appears that no matter what model was used, the results were nearly the same.

In an effort to explain the lack of difference in model performance, the patterns of demand for the interval items were examined. Previously, the eighteen months of demand had been graphed using the 'SCAT' command and a line fitted to the points using the 'LINE' command. Residual points were plotted around the fitted line by using the 'SCAT' command after fitting a line to the random demand points. The result was a plot of the points around the fitted line, which graphically illustrated the degree of dispersion in the data.

The spread of points around the fitted line proved to be quite wide, which is to say that the data in general have a large inherent variance. Large variance in the demand data, greater than what would be normally expected, may very well explain the robustness of the different models. For best performance, the Regression model should have data that conform well to a linear structure. The closer the data point fit to a trend line, the better the model performance will be. The Exponential Smoothing model is set up to handle more variable data; i.e., is more adaptive in nature. The A3RSR technique attempts to break down outliers and wild

variation to discover an underlying structure. Beyond a certain point, however, the amount of variability and/or bias may be too large as to completely obscure any reasonable attempt to discover underlying structure.

Further investigation was thus undertaken to try to understand better all the factors impacting on the system. The demand was originated by the Pharmacy when they ordered the FSC 6505 items from the Supply Department, so the origins of the orders inside the Pharmacy were investigated.

The Pharmacy Officer was interviewed concerning the ordering procedures in effect within his Division. Supplementary information was also sought concerning the dollar value and unit amount of material surveyed (destroyed) on a monthly basis. The reason for the survey information was to discover if the excessive fluctuation observed in the data had caused the Pharmacy to overstock material, which then expired and had to be destroyed. If the Pharmacy overstocked material due to excessive random demand, then the demand histories used by the Supply Department would cause a corresponding overstockage in the Supply Department. The Supply Department surveyed $1,042.28 worth of expired material from January through June of 1978, so it was hoped that a comparison could be made to see if overstocking due to excessive demand affected both areas.

Within the Pharmacy, the ordering of FSC 6505 items is dependent on two factors; 1) The demand for material at the Pharmacy window (from 'customers' of the Pharmacy), and 2)

The determination by the person doing the ordering for the Pharmacy of the requirements for material to support the demand at the window. The demand excountered at the window is certainly the central source of randomness in the system; everything else should be dependent upon it. Even though the window demand is random, a means of measuring that demand should exist to give the person doing the ordering some idea of the demand history of that item.

Unfortunately, no means currently exists for measuring the window demand within the Pharmacy. No system is in effect to give any idea of the demand history for an item. The reason for this (given by the Pharmacy Officer) is that only a week supply of FSC 6505 items are kept on the shelf in the Pharmacy, so a system for recording demand is not felt necessary. A system has been proposed whereby the Data Processing Division will provide to the Pharmacy on a line-item basis a four month demand history. Within the Pharmacy, it was felt that this report would not be used even if provided. The Pharmacy personnel felt that they were performing at an optimal level, and did not need a demand history report.

The process of ordering from the Supply Department was then investigated. The ordering system is subjective in nature; the person doing the ordering keeps a card on each line item used, and records on that card the date and quantity to be ordered that he subjectively determines he needs. Each time he orders, he consults his previous order amount, and orders what <u>he thinks</u> will fill the demand within the

next week. The person doing the ordering has no idea what the real past demand has been at the window, so his order amounts are truely subjective and tend therefore to be highly biased. The records concerning material surveyed within the Pharmacy are kept for only narcotic items, as this is required by Federal law. Other FSC 6505 material surveyed is either thrown away without recording, or, in the case of material purchased from commercial sources, is given back to the drug salesmen for replacement. No estimation of the dollar amounts or volume of surveys can be made, as no records are kept. The Pharmacy has no objective system to determine how great the demand is at the window, how great the demand has been in the past, or how much material is surveyed each month.

The lack of data collection within the Pharmacy concerning demand, the lack of survey information, and the subjective ordering system certainly contribute to excessive fluctuation in the demand data, with the effect of obscuring the true demand pattern. Three factors are needed in the Pharmacy to establish an objective ordering system;

1) Measurement of the random demand encountered at the Pharmacy window
2) Measurement of the amount of material surveyed whether required by law or not
3) Measurement of the amount of material needed from the Supply Department to meet the demand encountered at the window

Within the Pharmacy, there is no objective system to satisfy

the requirements for these measurements. Therefore the amount of material ordered from the Supply Department can vary widely on a number of factors. Seasonal demand may cause temporary stockouts in the Pharmacy that will cause the person ordering material to overstock, different personnel may be doing the ordering, excess material ordered one month may be depleted over a number of months distorting the demand figures, and the desire to conform to funding limits may influence order amounts. In a system such as this, it is easy to understand why no model can perform appreciably better than any other.

VI. RECOMMENDATIONS

Since excessively variable data renders the performance of differing forecasting models nearly equal, steps should be taken to reduce the variation in the data, or at least account for it better. The demand data from the Pharmacy is dependent on three factors;

1) The random demand encountered at the window
2) The amount of material surveyed
3) An objective system to determine requirements for the upcoming period

The Pharmacy should establish a system to measure the demand for drug items at the window. This is a first step in establishing an objective system for the ordering of material. The building of a demand history will both aid in ordering material and aid the Pharmacy personnel in

understanding the material they handle. With a good demand history they can identify seasonal items, items with changing demand, and items needing special handling.

The amount of material surveyed should be recorded within the Pharmacy for their internal use. Survey data, when used in conjunction with the demand encountered at the window, gives a better picture of material requirements to the personnel doing the ordering for the Pharmacy. Secondarily, accurate survey records aid in drug control, reducing the possibility that theft may be explained as material surveyed.

To begin establishing an objective ordering system, the Pharmacy should work with the Data Processing Division in setting up the demand history program that currently is being considered. The system should give the Pharmacy personnel average demand data for the past four months, which will at least give the personnel doing the ordering an idea of how mcuh material should be ordered. The user involvement of the Pharmacy in the program development will help in assuring that a viable program will be developed, one that will be utilized rather than left on a desk. Development of this program will be an important step in reducing demand data variance, and is best undertaken by both departments involved.

Average demand data is more objective than an estimation of requirements based on previous order amounts. If average demand appears to give enough information for ordering purposes, no further system development need be undertaken. If excessive stockouts or surpluses result, further refinements

can be undertaken to refine the ordering system to make it more responsive. Whatever system is implemented, it should be at least as good or better than the subjective system in operation at the present time.

Once an objective system is in place and the randomness in demand data reduced, the study should be rerun to evaluate the models under the new demand circumstances. With less random and more representative demand data, model performance differences should be more pronounced, and a better evaluation of the best model to use for demand forecasting should be possible.

APPENDIX A

RASC CARD FORMAT

CARD COLUMN	
1-3	Document Identifier (BA5)
4	Condition Code
5-6	VOSL Item Leadtime in Months
7	Overflow Indicator
8-20	National Stock Number (NSN)
21	Logistic Management Code "F" or "G" (9M Cog)
22	Blank
23-24	Unit of Issue
25-30	On-Hand Quantity
31-35	Due Quantity
36	Acquisition Advice Code
37-40	Back Order Quantity
41	* To denote gas cylinder item
42-46	Cylinder Pool Requirement/VOSL Reorder Point
47-51	PWRS Reservation Quantity
52-54	VOSL QMC (One Decimal)
55-56	Account/Cog (1B, 1W, 9A, 9C, etc.)
57-62	Demand (12 Months)
63-66	Demand Frequency (Each Quarter)
67-69	Routing Identifier (From)
70-76	Unit Price
77-80	NSO Quantity

APPENDIX B

PROGRAM P5D, HISTOGRAMS AND UNIVARIATE PLOTS

Job Control Language

1. Identification Card
2. // EXEC BIMED, PROG=BMDP5D
3. // SYSIN DD *

Program P5D Control Language

```
4.  /PROBLEM   Title is 'FSC 6505 Line Item Histogram Plot'.
5.  /INPUT     Variables are 2.
6.             Format is '(56X,F6.0,7X,F7.2,4X)'.
7.  /VAR       Names are '12MODMD',Uprice.
8.             Blanks are missing.
9.  /PLOT      Type=Hist, Norm, Cum, Chist.
10.            Variable = '12MODMD', Uprice.
11. /END.
```

Data Cards

Deck of 1,006 Line Item Cards

End Card

12. //

APPENDIX C

A3RSR FORECAST PROGRAM

This program uses the 100 card Source Deck as input. The FORTRAN Program converts the Source Deck into a file named FT08F001, which is then converted into APL format by the APL commands. A file named 'DEMAND' is created by the APL commands, and the individual items in the file are run through the A3RSR program of the OA366Ø Public Library.

1. Read Source Deck into outside card reader. (name 'file FT04F001')
2. Run source Deck through following FORTRAN program:

```
      REAL DATA (100,22)
      N=100
      READ(4,1) ((DATA(I,J), J=1,22), I=1,N)
    1 FORMAT(1X,F2.0,1X,19F4.0/2F4.0)
      DO 10 I=1,N
   10 WRITE (8,2) (DATA(I,J),J=1,21)
    2 FORMAT (F3.0,1X,F5.0,19F5.0)
      STOP
      END
```

3. The APL mode is entered, and the following APL program created;

```
)COPY 999 CMSIO CMSRD
DEMAND    1 CMSREAD 'FILE FTO8F001'
STOCKNO    , 90 2    DEMAND
```

)WSID INVENTORY

)COPY 20A3660 ESSENTIALS

4. The APL Program reads the FORTRAN file FT08F001 and converts it to an APL file named DEMAND.

5. Individual line items are selected from the 'DEMAND' file and run through the A3RSR program;

```
D1 ← DEMAND (1;)
C ← A3RSR D1
C
```

6. At the command ' C ', the A3RSR forecast is printed out, and the last value is taken as the forecast for the coming period.

APPENDIX D

EXPONENTIAL SMOOTHING PROGRAM

This program developes Exponential Smoothing forecasts using the Source Deck as an input. Alpha values are adjusted by use of the command 'Al=X' where X is the alpha value desired. The program develops forecasts for two months at a time, and uses the means of the first three demand values as the forecast for the last period in the first forecast calculation.

Job Control Language

1. Identification Card
2. // EXEC FORTCLG
3. // GO. SYSIN DD *
4. //

Exponential Smoothing FORTRAN Program

```
      DIMENSION X(20), Y(20,100), STOCK(100), Z(20,100)
      REAL*8 STOCK
      DO 10 I=1,18
      X(I)=I
   10 CONTINUE
      DO 20 J=1,100
      READ(5,100,END=99) STOCK(J),(Y(K,J),K=1,20)
  100 FORMAT(A8,18F4.0/2F4.0)
   20 CONTINUE
   99 CONTINUE
      WRITE(6,610)
```

```
 610  FORMAT(' STOCK NUMBER   PREDICTION')
      DO 200 I=1,100
      A1=.1
      A2=1.-A1
      Z(1,I)=A1*Y(1,I)+A2*((Y(1,I)+Y(2,I)+Y(3,I))/3.)
      DO 300 J=2,18
      Z(J,I)=A1*Y(J,I)+A2*Z(J-1,I)
 300  CONTINUE
      WRITE(6,600) STOCK(I), Z(18,I), A1,II
 600  FORMAT(2X,A8,8X,F8.1,10X,F5.0,I5)
      A1=.05
      A2=1.-A1
      Z(1,I)=A1*Y(1,I)+A2*((Y(1,I)+Y(2,I)+Y(3,I))/3.)
      DO 400 J=2,18
      Z(J,I)=A1*Y(J,I)+A2*Z(J-1,I)
 400  CONTINUE
      WRITE(6,600) STOCK(I), Z(18,I), A1,II
      A1=.1
      A2=1.-A1
      Z(1,I)=A1*Y(1,I)+A2*((Y(1,I)+Y(2,I)+Y(3,I))/3.)
      DO 310 J=2,19
      Z(J,I)=A1*Y(J,I)+A2*Z(J-1,I)
 310  CONTINUE
      WRITE(6,600) STOCK(I), Z(19,I), A1,II
      A1=.05
      A2=1.-A1
      Z(1,I)=A1*Y(1,I)+A2*((Y(1,I)+Y(2,I)+Y(3,I))/3.)
      DO 410 J=2,19
```

```
      Z(J,I)=A1*Y(J,I)+A2*Z(J-1,I)
  410 CONTINUE
      WRITE(6,600) STOCK(I), Z(19,I), A1,II
  200 CONTINUE
      RETURN
      END
```

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